Wind energy research in Denmark: International cooperation

Hansen, Jens Carsten; Hummelshøj, Poul

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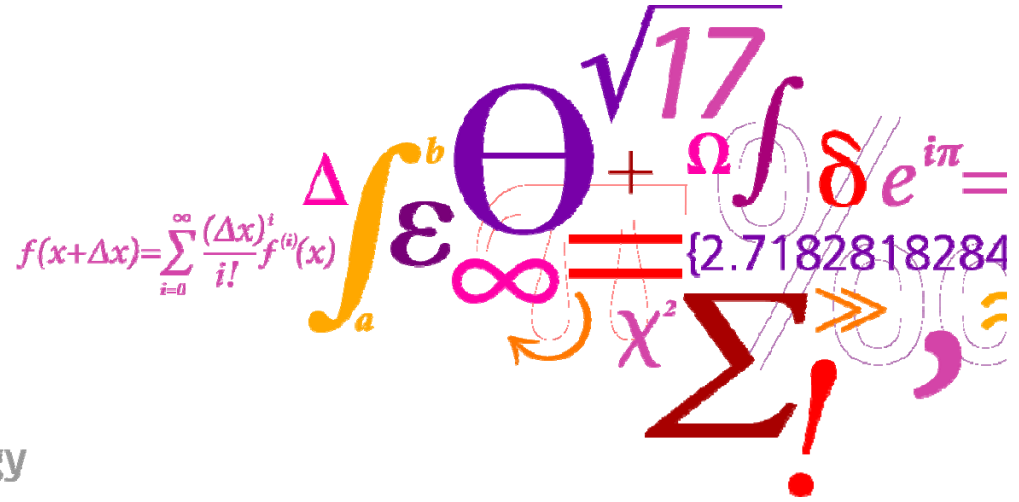
International cooperation

Jens Carsten Hansen and Poul Hummelshøj

Risø National Laboratory for Sustainable Energy
Technical University of Denmark



Risø DTU
National Laboratory for Sustainable Energy

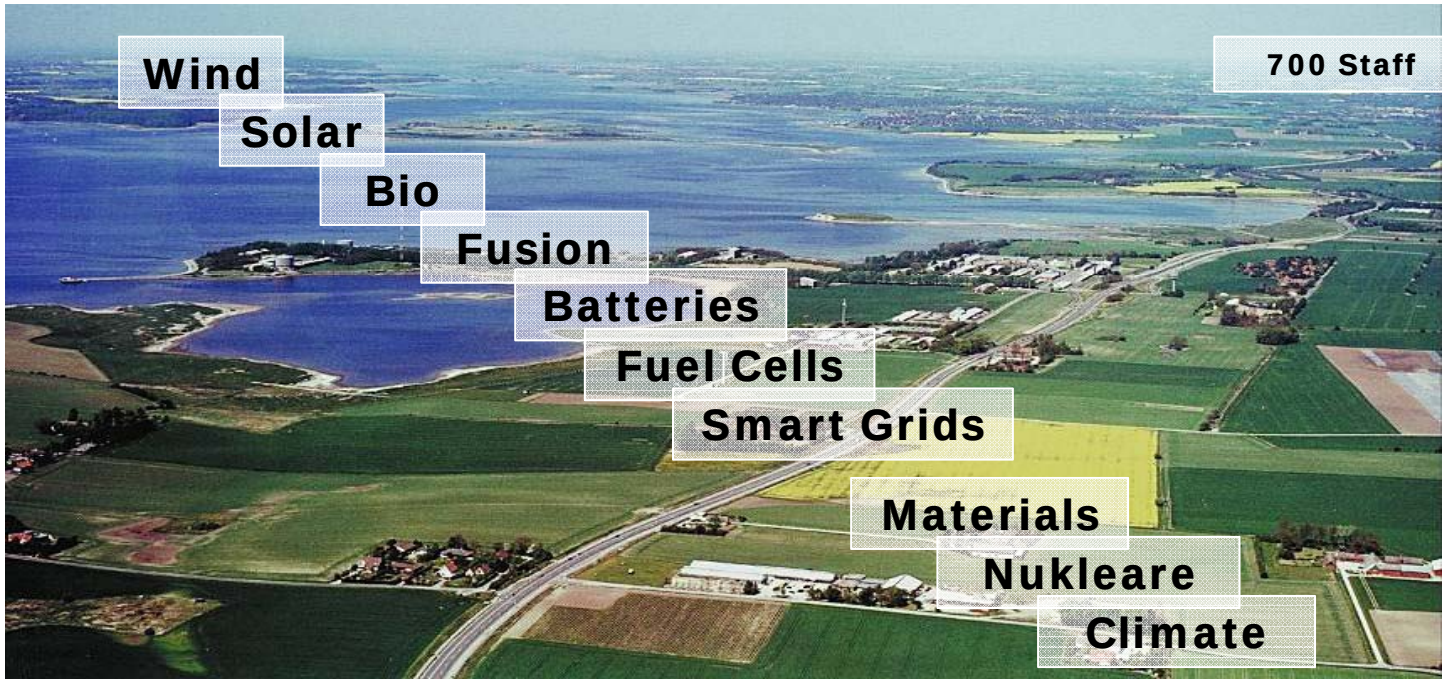
Some Risø history in brief

- **1954** Nuclear Energy Committee headed by Niels Bohr
- **1958** 3 nuclear reactors under construction
- **1976** Wind energy research starts
- **1985** No Nuclear Power in Denmark energy plans
- **2000** Decommissioning of the last nuclear reactor is
- **2005** Sustainable energy central in strategy
- **2007** Part of Technical University of Denmark (DTU)

Risø is part of the Technical University of Denmark (DTU)

- January 2007, Risø National Laboratory merged with the Technical University of Denmark (DTU)
- Research, education, innovation and assistance of public authorities
- 7,000 students
- 4,200 employees, 2,000 of whom are scientists
- Annual revenue of DKK 3.2 billion

Risø DTU is the national laboratory for sustainable energy



Key activities at Risø DTU

Problem-driven research and innovation in Wind Energy

- basic and applied research
- development and innovation
- Selected services & testing

Education and training:

- Master in Wind Energy
- Masters in Sustainable Energy
- Selected lectures
- PhD-programme and PhD-courses
- Training courses for industry

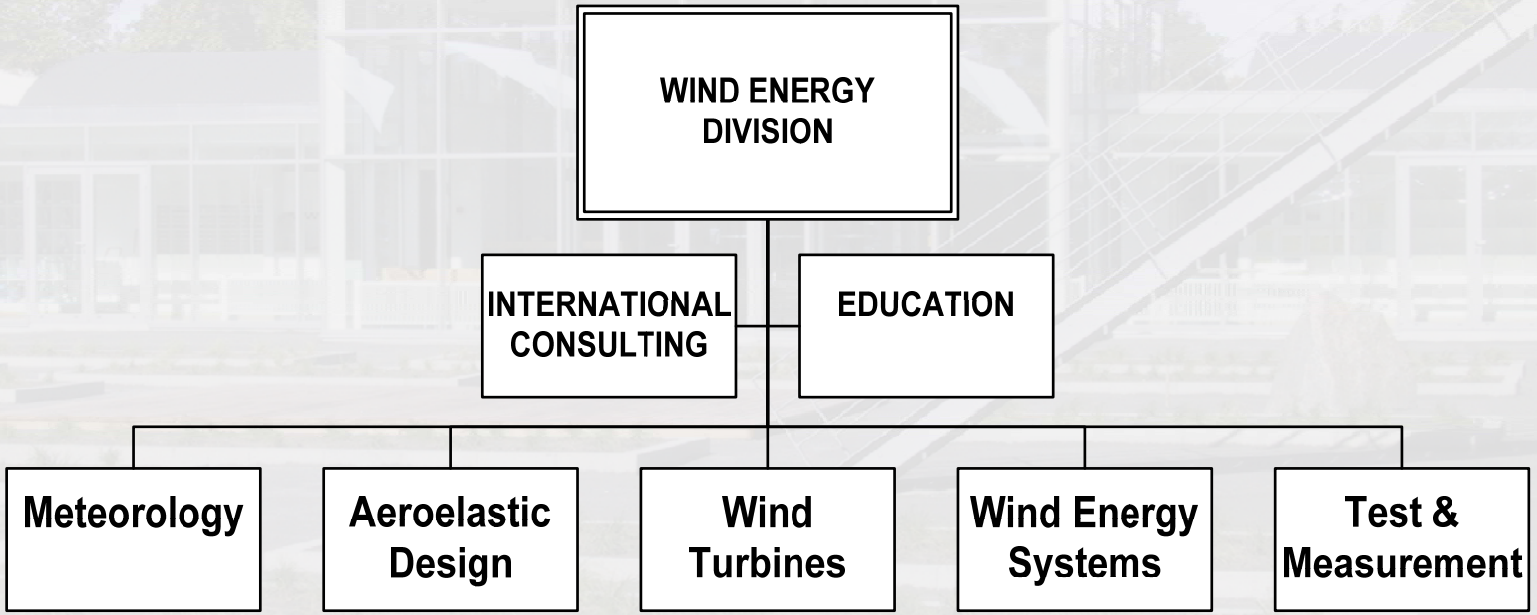
Experimental facilities

Large Projects

- Research programmes
- Development programmes
- Authorities
- Industry
- Power sector

Wind Energy R&D at Risø DTU
Technical University of Denmark

Wind Energy Division



Systems Analyses Division

Materials Research Division

Intelligent Energy Systems

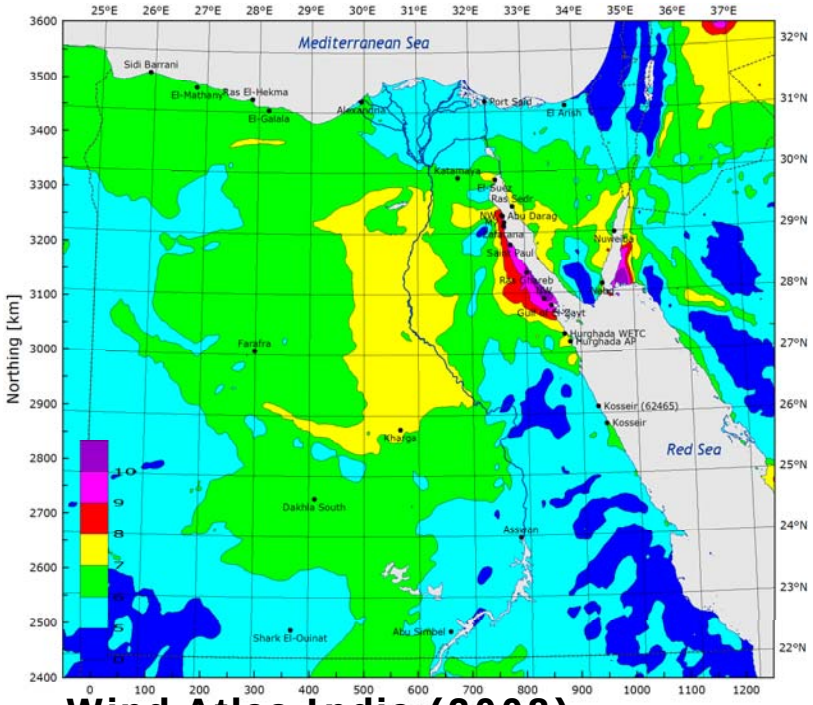
Wind Power Meteorology - 1

Wind Atlas Method and tools

Wind Atlas Denmark (1981)

Wind Atlas Europe (1989)

Wind Atlas for Egypt (2006)



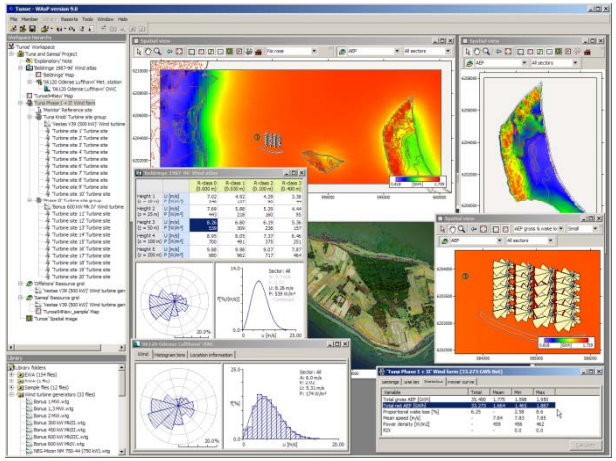
Wind Atlas India (2008)

Wind Atlas NE China (2010)

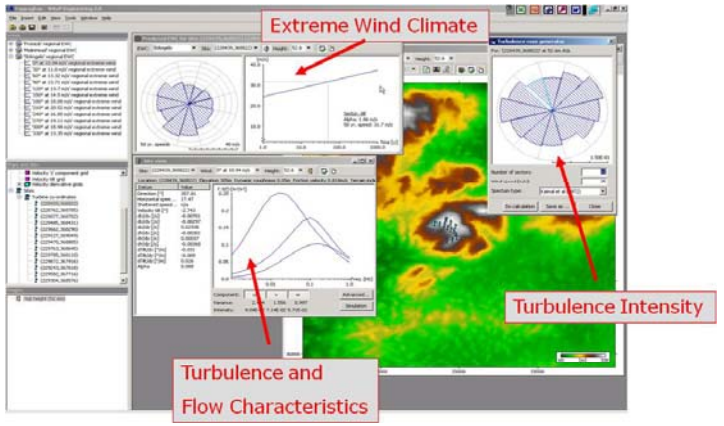
Wind Atlas South Africa (2011)

Global WA

WAsP – wind resource assessment



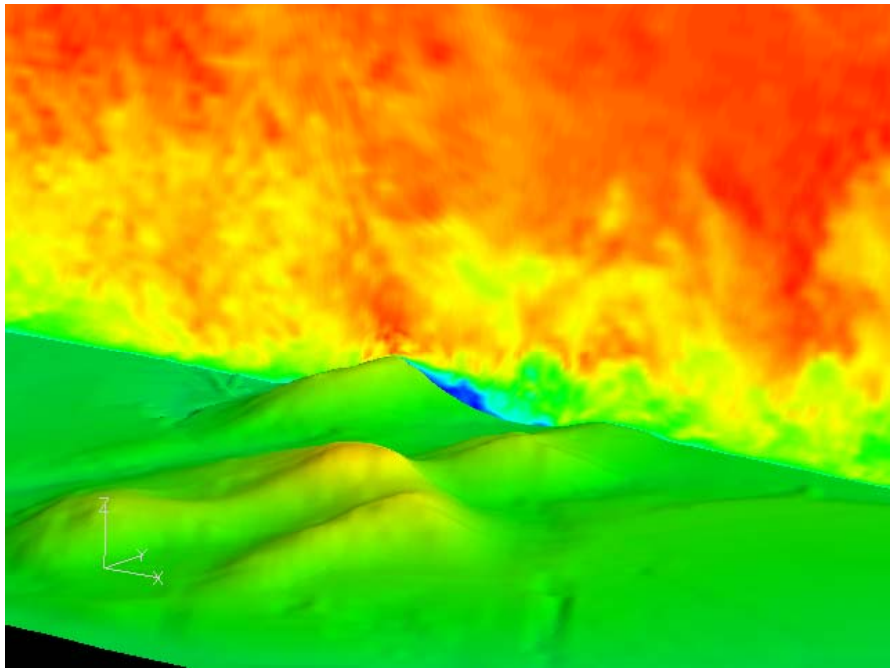
WAsP Engineering – design conditions



Wind Power Meteorology - 2

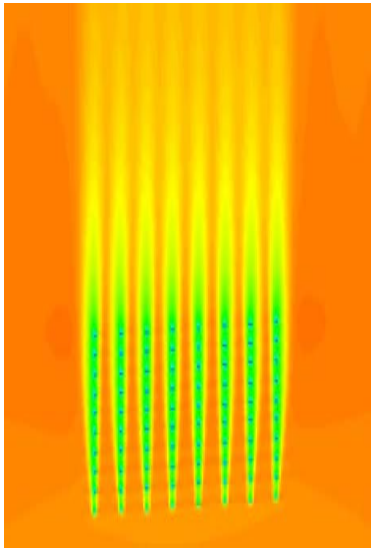
Research Agenda - Wind Conditions

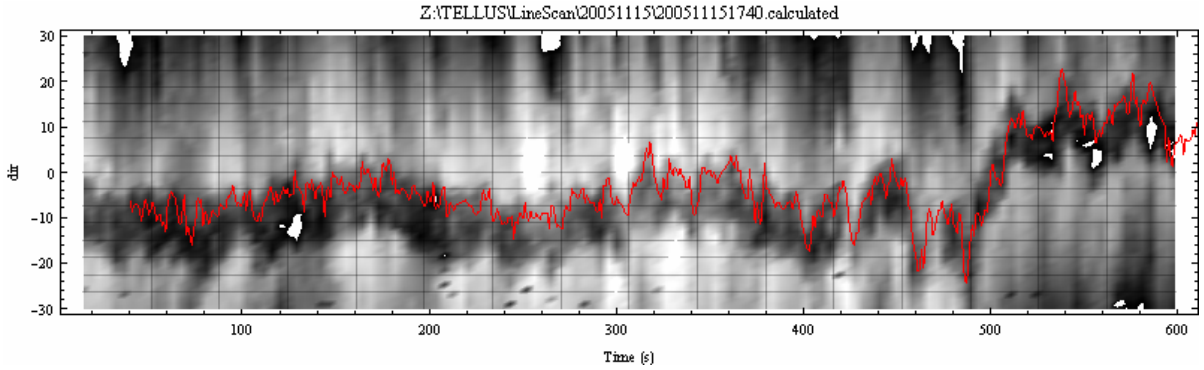
- Siting
- Design
- Forecasting
- Resources
- Extreme winds
- Vertical profile
- Turbulence
- Complex terrain
- Wakes
- Offshore



CFD of wind over complex terrain

Wind Power Meteorology – 3
Wind farms





- Wind turbines wake effect
- Multiscale CFD turbulence models (ABL + wake)
- Wind farm data analysis
- Influence of atmospheric stability
- Dynamic wake meander model
- Wind farms shadow effect
- Micro-mesoscale modelling
- Wind farm layout optimization

Wind turbine load and response - HAWC2

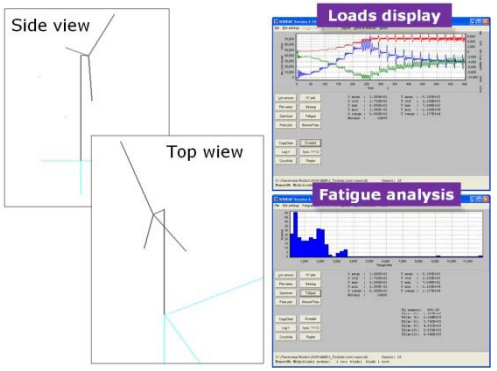
A tool for simulation of wind turbine load & response in time domain.

- Normal onshore turbines; 3B, 2B, pitch control, (active) stall
- Offshore turbines (monopiles, tripods, jackets)
- Floating turbines

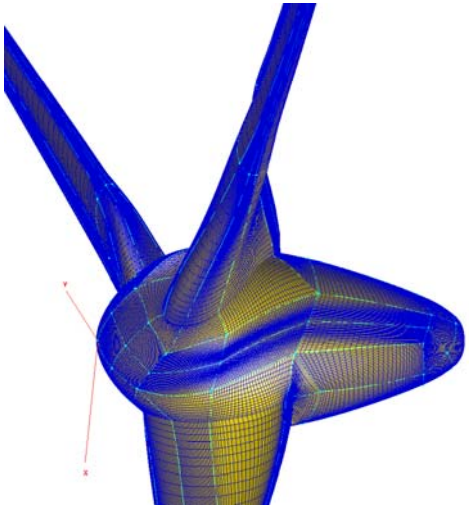
Based on a multibody formulation – flexibility

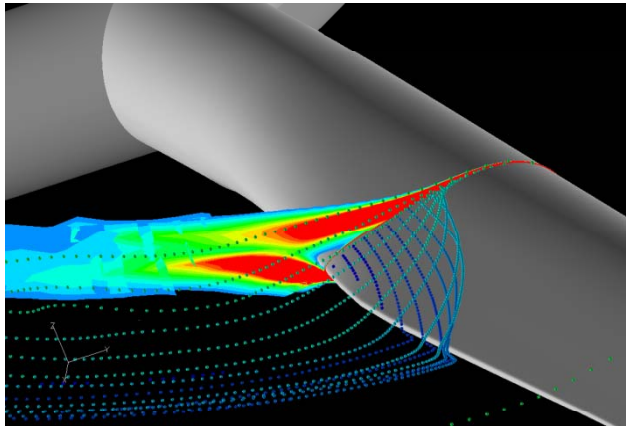
A knowledge platform

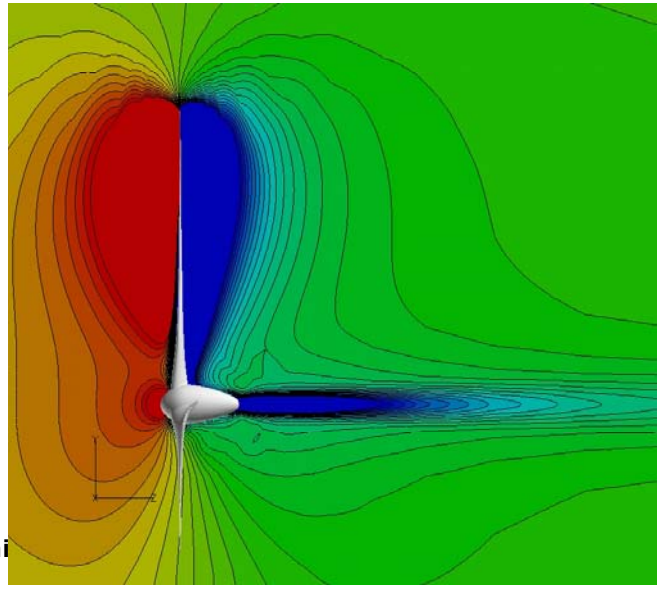
- New research/models are implemented and updated
- Core is closed-source
- Submodels are open-source

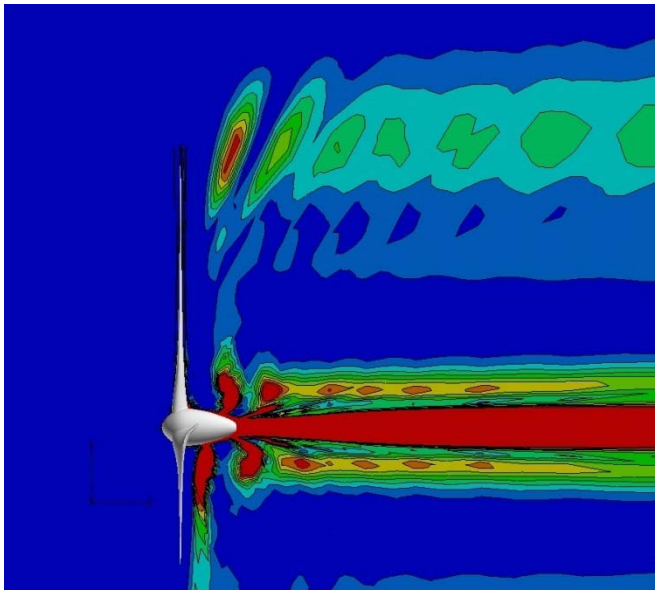


Advanced flow and rotor analysis









Red is high pressure

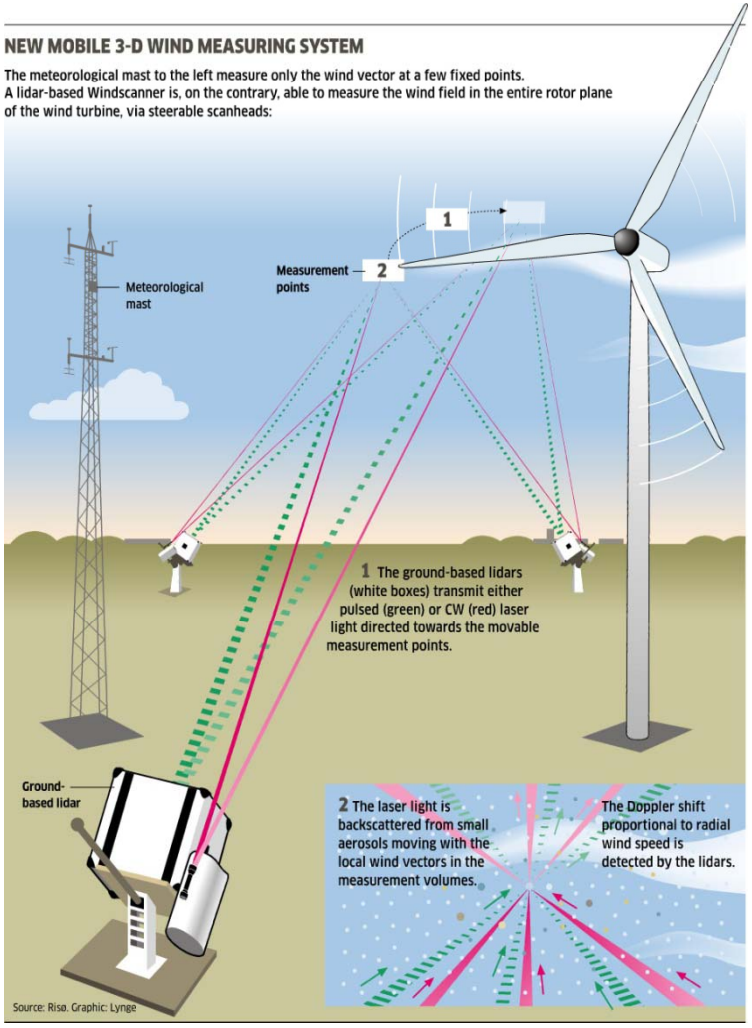
Blue is low pressure

Risø Test Stations – Prototype Testing

5 test beds
< 165 m
< 8 MW
Spacing 300 m

7 test beds
< 250 m
< 16 MW
Spacing 600 m

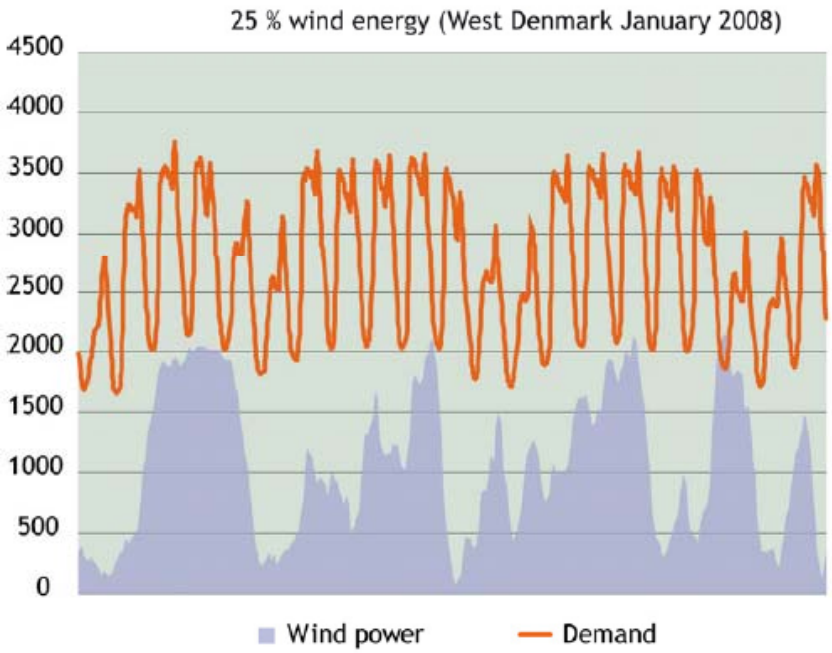
Windscanner.DK



Lidar-based wind and turbulence measurements for research, siting and control

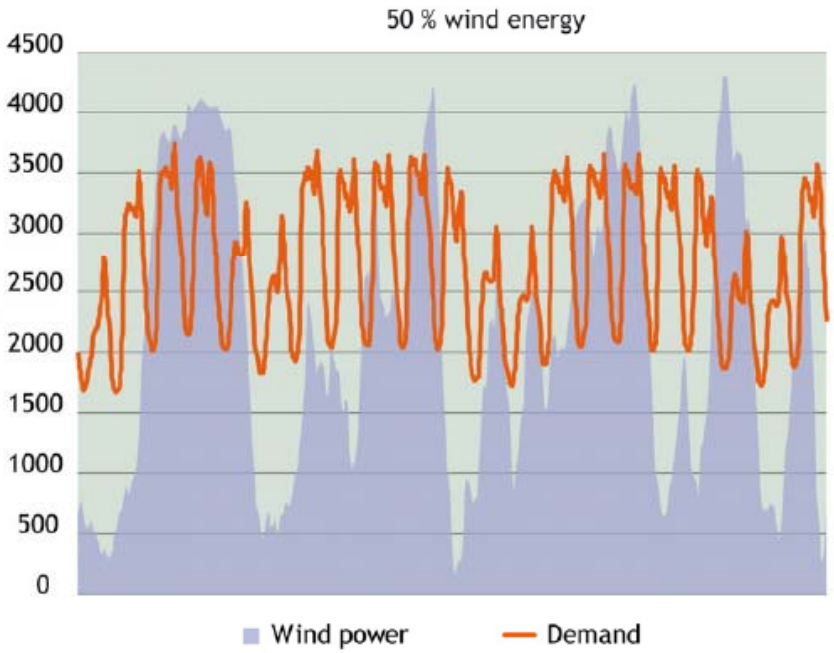
Wind integration: The Danish Target

2008



- 20% of electricity consumption met by wind power – annual average
- Around 3GW installed wind power capacity
- For a few hours in a year wind power covers the entire Danish demand

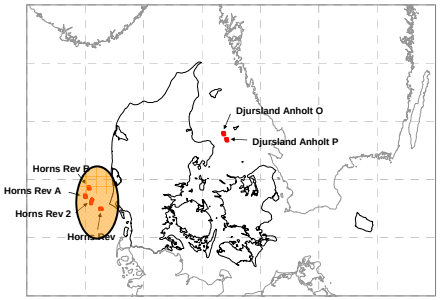
2025

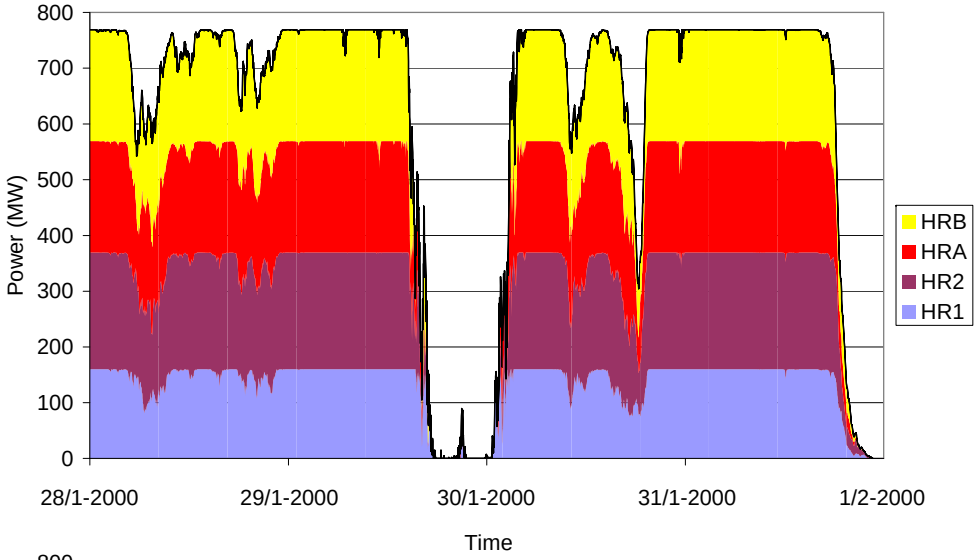


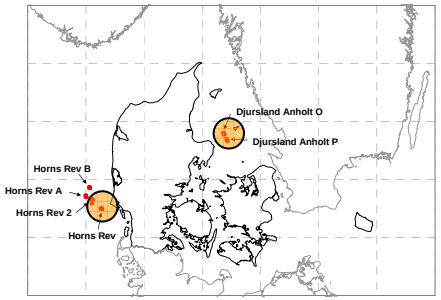
- 50% of electricity consumption to be met by wind power – annual average
- Around 6GW installed wind power capacity
- Wind power production will often exceed the Danish demand

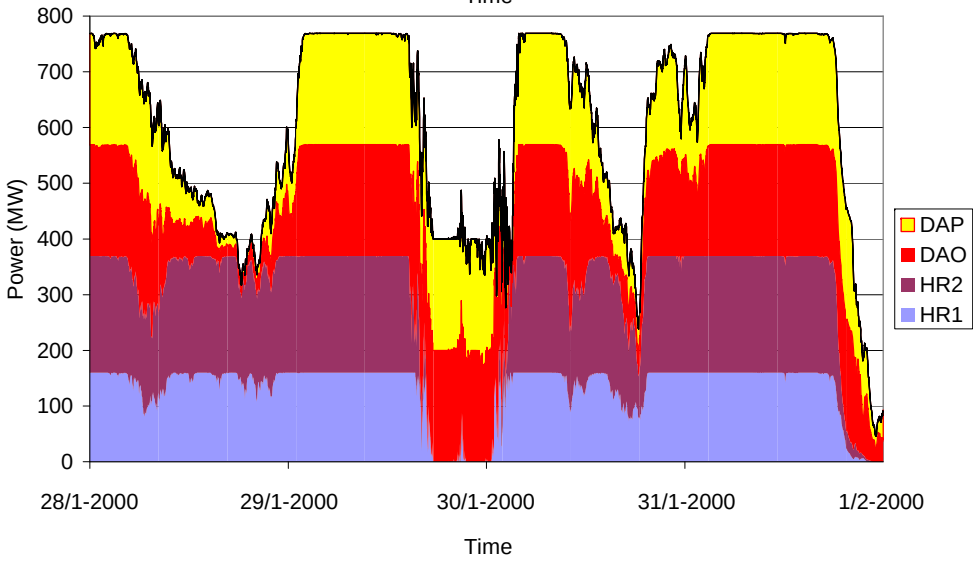
Source: Energinet.dk - EcoGrid

Power fluctuations – the two study cases







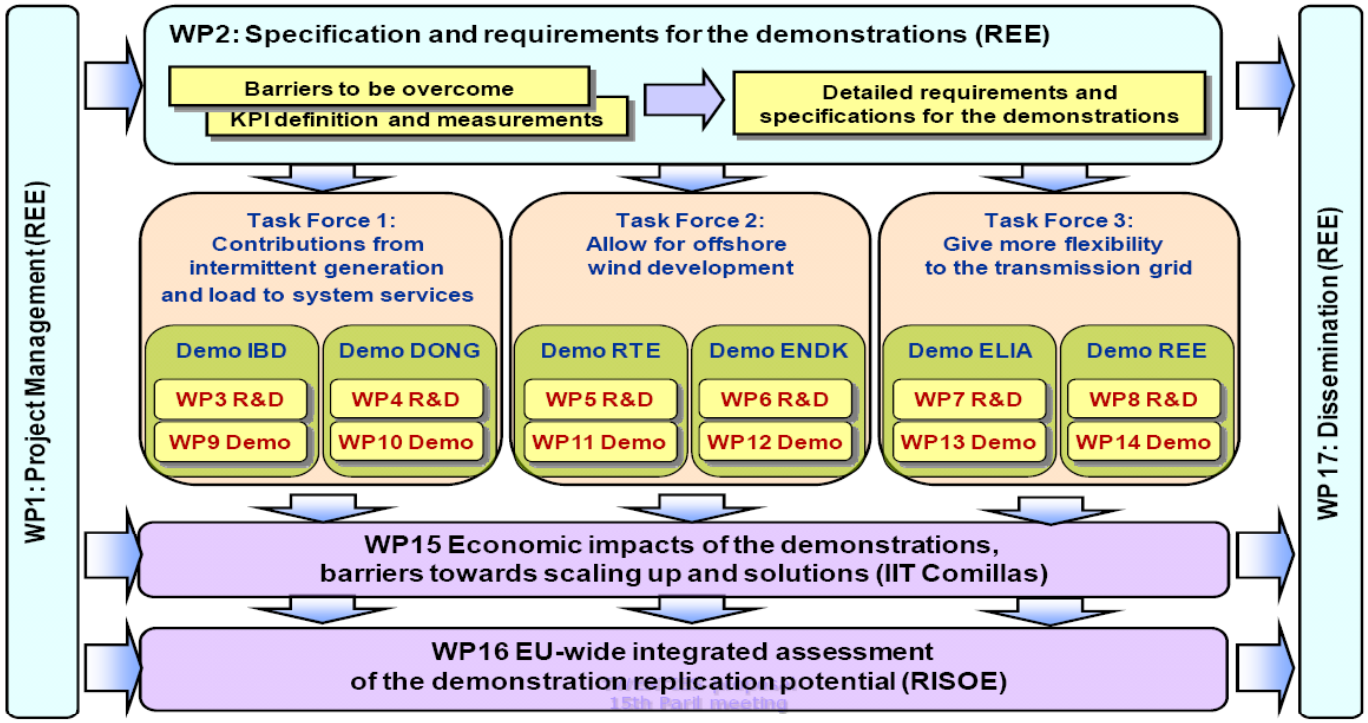


EU FP7 - TWENTIES

TRANSMISSION SYSTEM OPERATION WITH LARGE PENETRATION OF WIND AND OTHER RENEWABLE ELECTRICITY SOURCES IN NETWORKS BY MEANS OF INNOVATIVE TOOLS AND INTEGRATED ENERGY SOLUTIONS

- 26 partners, 35 M€, Starts Feb2010

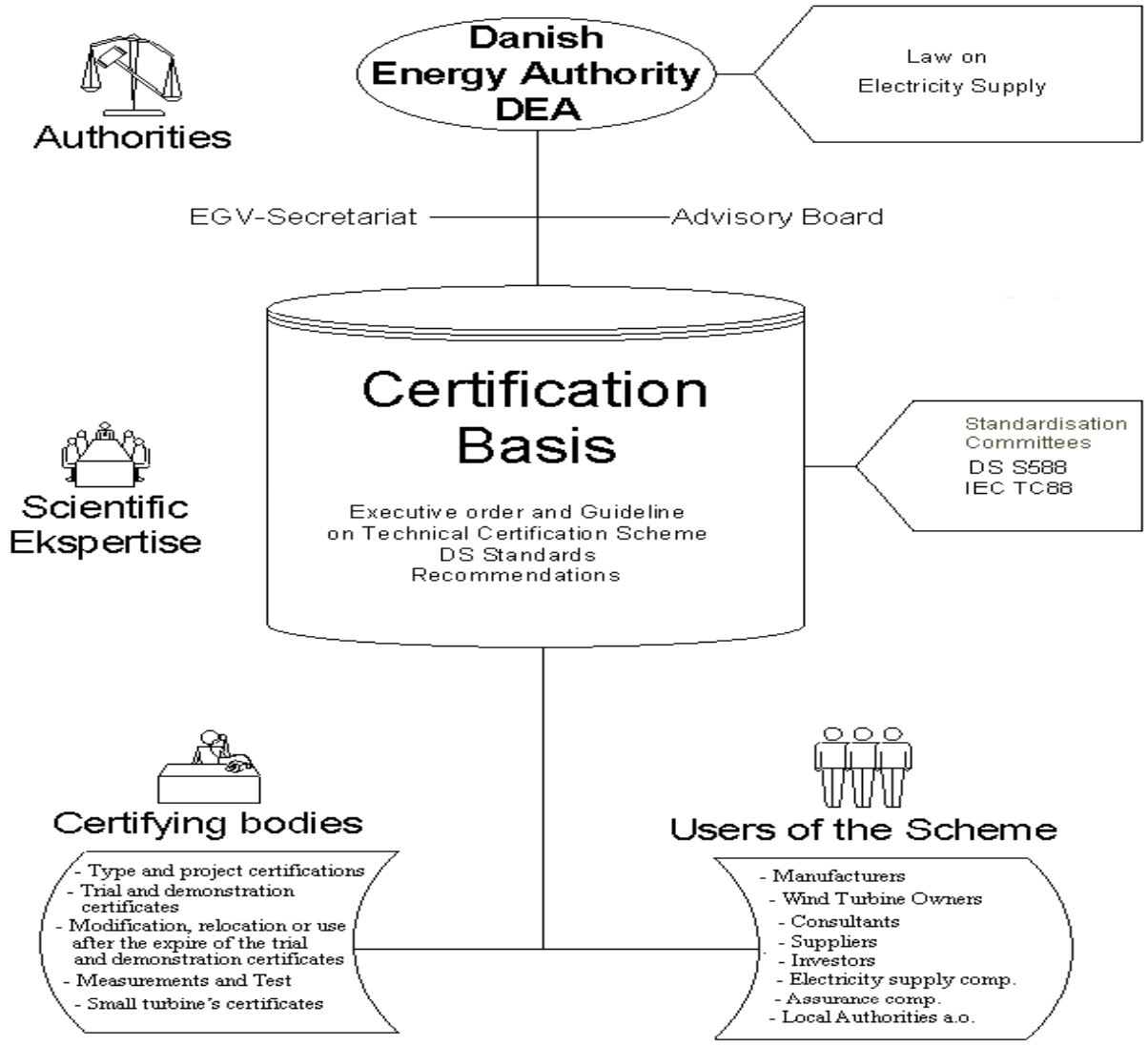
Risø DTU (1.5 M€)



- WP2 – KPI
- WP6 – Storm control demonstration with WP12 EnergiNet Demo
- WP16 – Up-scaling assessment of demonstrations to EU-wide scale – i.e. modelling

- ✓ **Task force 1:** what are the valuable contributions that intermittent generation and flexible load can bring to system services
- ✓ **Task force 2:** what can the network implement to allow for offshore wind development?
- ✓ **Task force 3:** how to give more flexibility to the transmission grid?
- ✓ **Overall:** how replicable are the results within the entire pan-European electricity system?

Danish Scheme for Certification of Wind Turbines



International wind turbine standards - IEC

a) Safety & functional requirements

↓

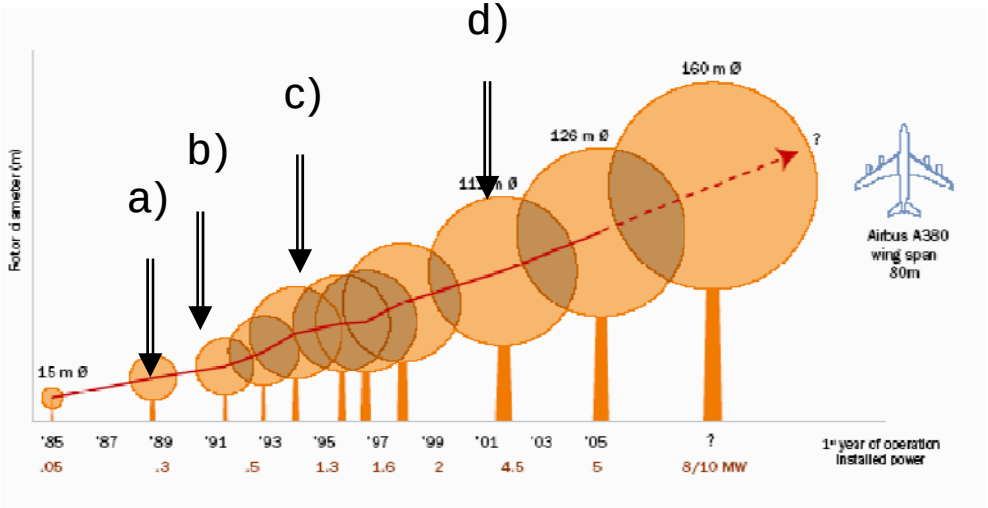
b) Test methods

↓

c) Certification procedures

↓

d) Interfaces & Component

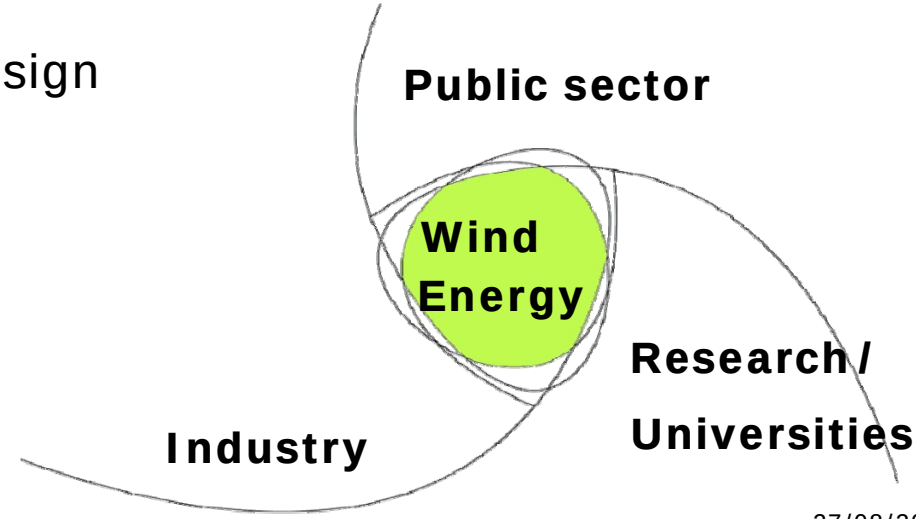


IEC TC88: IEC 61400 standards series:

IEC 61400-1 Design requirements
IEC 61400-2 Small wind turbines
IEC 61400-3 Design requirements for offshore wind turbines
IEC 61400-4 Gears for wind turbines
IEC 61400-(5) Wind Turbine Rotor Blades
IEC 61400-11, Acoustic noise measurement techniques
IEC 61400-12-1 Power performance measurements
IEC 61400-13 Measurement of mechanical loads
IEC 61400-14 Declaration of sound power level and tonality
IEC 61400-21 Measurement of power quality characteristics
IEC 61400-22 Conformity Testing and Certification of wind turbines
IEC 61400-23 TR Full scale structural blade testing
IEC 61400-24 TR Lightning protection
IEC 61400-25-(1-6) Communication
IEC 61400-26 TS Availability
IEC 61400-27 Electrical simulation models for wind power generation

Potentials for cooperation

- MSc programmes
- PhD programmes
- Basic research
  - Wind resource mapping
  - Wind farm siting and performance
  - Flow modeling and aerodynamics
  - Load conditions and design criteria; (standards)
  - Grid integration
- Software/training
- Technology development
  - Applied research
  - Analysis
  - Testing & measurements
- Dialogue & access to Danish wind cluster



Risø DTU wind energy research alliances

- Research Consortium for Wind Energy
  (DK Universities and Technological Service Institutes)
- EERA (EU)
- EAWE (EU)
- TPWind (EU)
- NREL, Sandia (US)
- Sino Danish Center (China)
- MoU with MNES (India)
- MoU with SANERI (South Africa)


Thank you for your attention